Extreme Value Statistics for Predicting Pitting Damage – A Tour

Overview

In this tour, we will show examples of applications of Extreme Value Statistics for predicting pitting damage. Specifically, we will show how to predict

1. The depth of the deepest pit in the engineering structure or laboratory systems as a function of time and the surface area of the system;
2. Probability of failure for a given penetration depth and the area of the system as a function of observation time.
3. Probability of failure for a given observation time and the area of the system as a function of penetration depth.
4. Probability of failure for a given penetration depth and observation time as a function of the area of the system.

At this point you should be very familiar with entering data into OLI Analyzer. Also, you need to know the foundation of Extreme Value Statistics (Aziz, 1956, Kowaka et al. 1994, Laycock et al. 1990, Engelhardt and Macdonald, 2004).

Example 1: Corrosion of aluminum alloy in tap water

In this example, we will consider the classical data for pitting corrosion (Aziz, 1956). In this paper, we can find particularly the experimental data for the maximum pit depths developed on Alcan 2S-O coupons with area s ≈ 129 cm^2 immersed in Kingston tape water at 25 ^{0}C (see **Table 1**).

Table 1 *Maximum pit depth (in µm) developed on Alcan 2S-O coupons with immersed in Kingston tape water for different observation time*

Coupon #	One Week	One Month	Three Months	Six Month	One Year
	7 days	30 days	90 days	180 days	365 days
1	180	460	480	620	640
2	266	500	578	620	680
3	290	510	610	620	700
4	306	580	610	680	760
5	334	580	610	680	800
6	340	640	660	720	810
7	340	654	690	740	820
8	410	680	718	740	840
9	410	692	760	760	840
10	545	692	798	760	900

- Double-Click the ***Add Standard EVS Calculation*** icon

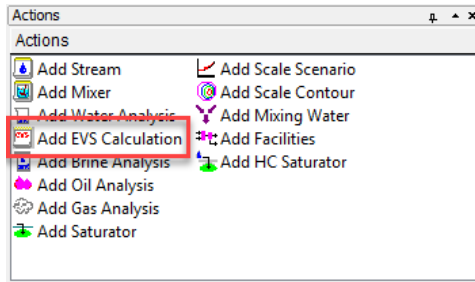*Figure 0-1 Starting EVS*

- Click on **Definition** tab and start by inputting experimental data.

Because all samples have the same area s = 129 cm^2 we input this value into **Default Value Area**. Other possible unit for area is m^2. The default value of pit depth is chosen to be in μm. Other possible units are Å, mm, ft, m, ft.

Because, in the first step, we will predict propagation of pitting damage in the same system (for the same coupons) we choose S = s = 0.0129 m^2.

The definition grid of the system should look like Figure 0-2.

Figure 0-2: The system definition.

There are experimental data for 5 different times (5 groups). Click on the button inside the red oval (see Figure 0-2) and type time 7 days in empty space below Elapsed (Figure 0-3).

Figure 0-3: Drop down-table for adding groups.

Insert data from the second column in **Table 1** into the Sample Group 01. Group 01 is representing 1 week.

After that, click on **Add Group** button (inside green oval), and in blank space type elapsed time = 30 days and insert all data from the third column for Sample Group 02. After inserting the data from Table 1 (from columns 1 and 3) the definition grid for EVS calculations should look like Figure 0-4.
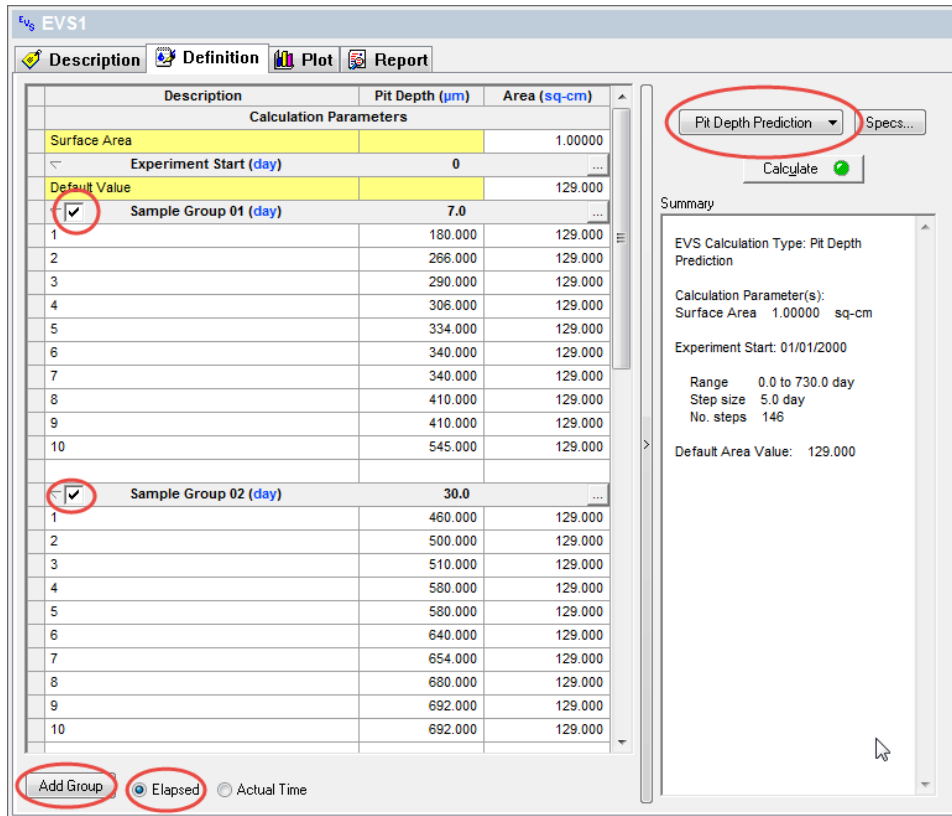

Figure 0-4: Specifying experimental data for depths of deepest pits (not completed)

Note the following:

- Here, for the description of different experiments we simply used the number of the corresponding row in Table 1. However, this description can be done in an arbitrary form.
- For each group, the order of samples relative depth can be arbitrary (not necessary in ascending order as in Table 1 or Figure 0-4).
- If coupons have different areas each area must be specified in the column **Area**.
- Radio button **Elapsed** (red ellipse in Figure 0-4) means the time after corrosion attack is used in calculations and namely this time is used usually in scientific publication. However, it is possible to use also Actual Time of the experiments.

Enter the remaining data from **Table 1** as new groups (columns 4 & 5), make sure the "Include boxes" are unchecked.

Figure 0-5 Adding more data, un-checking groups not to be considered in the calculation

Setting up the calculation (Pit depth prediction)

We will simulate the results of Aziz's experiments assuming that only data for short-time experiments (for 1 week and 1 month) are available. To include these data into calculations we must mark the boxes (red ovals in Figure 0-4). It can be done also by using the drop-down menu for adding groups (see Figure 0-4). All others groups (Groups 03 – 05) must not be marked.

Since we will predict corrosion on the samples with the same area, **the value of 129 cm^2** must be inserted into the property window Surface **Area**.

Description	Pit Depth (µm)	Area (sq-cm)
Calculation Parameters		
Surface Area		129.000
▽ Experiment Start (day)	0	...
Default Value		129.000

Figure 0-6 Setting Surface Area

In the drop-down menu for the Type of calculations (inside the blue oval) we choose **Pit Depth Prediction**. Now, click on the **Specs…** button.
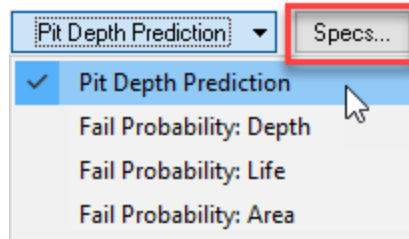

Figure 0-7 Selecting the type of calculation

The Survey Range category allows you to specify the range for the pit depth prediction survey. The default range is from 0 to 365 days that corresponds the available experimental data (Groups 01-05).

- Then click **Calculate** button.

Analyzing the results

When the calculations are finished, click on the **Plot** tab.

You will see a plot of the predicted mean value of the depth of the deepest pit, x_m and the plots of values $x_m - \sigma$ and $x_m + \sigma$, where σ is the standard deviation of x_m.

It is important to note that only data for short term experiments (for 1 week and 1 month) denoted by black circles are included in calculations. Other data, denoted by red diamonds are shown only for demonstrating the accuracy of prediction. Of course, these additional data may be included in calculations by marking the corresponding boxes.
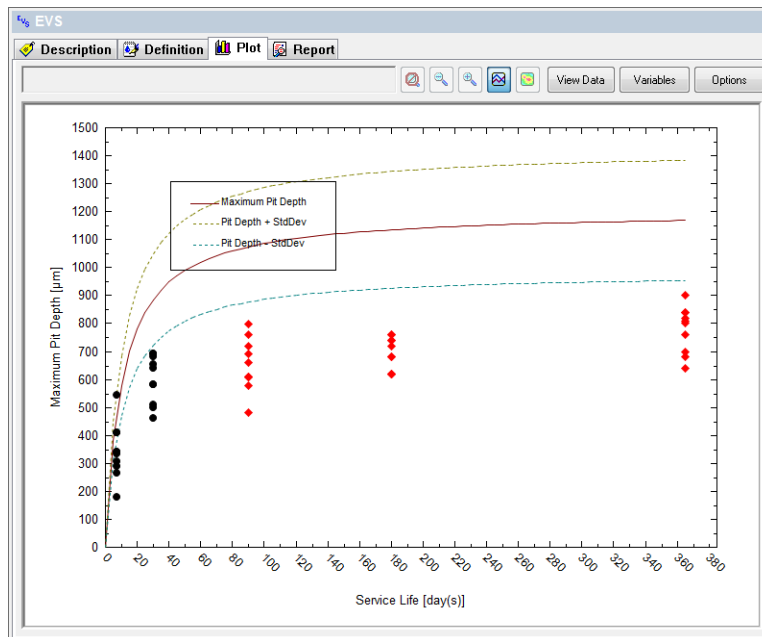

Figure 0-7: Predicted depth of the deepest pit. The experimental data for t = 1 week and 1 month are included into consideration.   S = 129 cm².

Of course, the accuracy of prediction increases when additional group of experiments are included into consideration.

- Click back on the **Definition** tab.

Include (check) 90 days so that you now have 7 days (1 week), 30 days (1 month) and 90 days (3 months).
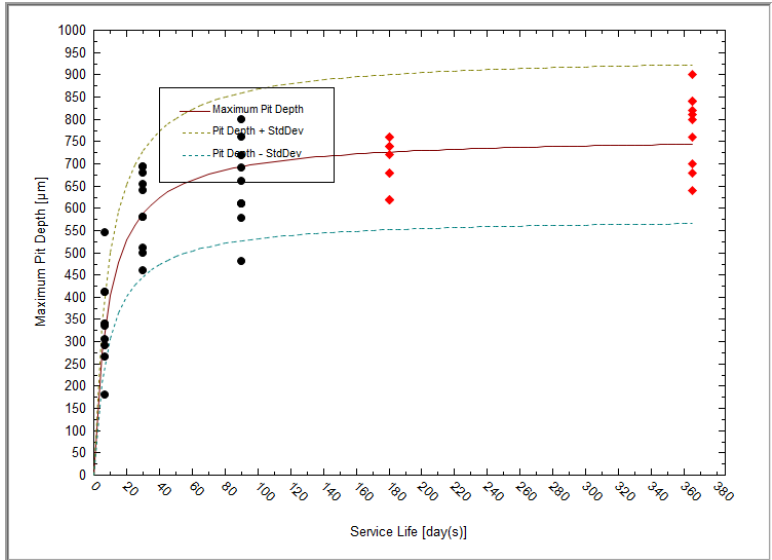
- Click **Calculate**

Figure 0-8:Predicted depth of the deepest pit. The experimental data for t = 1 week, 1 month, and 3 months are included into consideration.   S = 129 cm².